Farmer Education Program (PEPA) Resource Guide

Crop Planning and Production

Agriculture & Land-Based Training Association (ALBA)

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Adapted from *The Organic Agriculture Overview*, USDA, Cooperative State Research, Education, and Extension Service (CSREES), 2007.

Organic agriculture became one of the fastest growing segments of U.S. agriculture during the 1990s. According to USDA statistics, organic acreage in the United States has doubled, and consumption of organically produced products has increased 20 percent per year for the past decade. Today, 80 percent of organic products purchased on the market are fresh fruits and vegetables. The potential consumer demand for other organic products, like meat and processed foods, is wide open. Organic agriculture's importance was further solidified when the USDA implemented the first nationwide organic standards—the National Organic Standards—in 2002.

Organic agriculture is a very site-specific process. Farmers must often take information developed by others and adapt it to meet their local situations. This involves creativity, ingenuity, and a willingness to take certain risks—attributes that American farmers have exhibited from early days. Making the transition from conventional production to organic production is generally an information-intensive process.

Modern Organic Agriculture traces its roots to the "Dust Bowl" years of the 1930s. Tillage practices of that time were excessive and destroyed the structure of the soil. By exposing the organic matter contained in the soil to air, it, too, was destroyed (oxidized), thus compounding the loss of soil structure. In the book, *Plowman's Folly,* first published in 1943, Edward H. Faulkner laid the foundation for the modern practice of conservation tillage. He advocated minimum disturbance of the soil, and one of his primary goals was to conserve soil organic matter. In the popular press, Robert Rodale championed the concept that building a healthy soil, primarily by increasing the organic matter content, would produce healthy crops. Since his death, the Rodale Institute has continued the legacy of advocating the creation of a healthy soil as the basis for ecologically sustainable production systems. In addition, the publication of Rachel Carson's *Silent Spring* in 1962 caused a surge of concern over the state of the environment and a corresponding development of interest in organic farming. The 1960s and 1970s really saw the beginning of organic farming as a prevalent notion in public consciousness

But the term "organic" is not as easily definable as it might appear. To a chemist, an organic compound is simply one that contains carbon. Most synthetic pesticides are mostly carbon. To provide consumers with assurances that the "organic" products that they were purchasing were produced in a certain manner, certifying organizations were founded. The first was the California Certified Organic Farmers (CCOF) in the early 1970s. In time, similar organizations were formed in different parts of the United States and in other countries.

But there were differences in what were acceptable production practices to the various organizations. And once again, consumers were left wondering exactly what they were buying. This led to federal legislation, spearheaded by Senator Patrick Leahy of Vermont, that created the National Organic Standards for the production of organic agricultural products. Now certifying agencies inspect farms to determine whether or not the national standards are being applied. If they are, then the producer is permitted to use the official USDA seal for organically produced products. The national standards guarantee consumers that the products they purchase adhere to certain production guidelines.

Many reasons are cited by farmers for adopting organic practices, including: (a) economic (to lower input costs, to capture high value markets), (b) environmental (to conserve nonrenewable resources, to be an environmental steward), and (c) health (to reduce exposure to agrochemicals).

A further notion of organic agriculture that bears addressing is the persistent image of organic farming as being possible only on a very small scale. This impression has been enhanced by the high visibility of organic market gardens. These, of course, are small because market gardening — conventional or organic — is usually done on a smaller scale. Also, some organic market garden systems, such as Biointensive Mini-Farming, use highly labor intensive/low capital investment technologies. These have become popular among U.S. gardeners and, more importantly, with those concerned with Third World development, where such systems are especially relevant.

Learning Objectives

Become familiar with National Organic Program guidelines and principles.

1. **Explain integrated crop planning and crop selection strategies.**
2. **Identify and describe basic plant botany, plant functions, and which plant parts are harvested and sold at the market.**
3. **Describe plant life cycles and stages of development.**
4. **Compare and contrast the major types of cropping systems in organic agriculture.**
5. **Discuss and apply successive planting and season extension strategies.**
6. **Demonstrate how to prepare beds and different seeding strategies.**
7. **Practice fruit tree production**
8. **Demonstrate proper application of compost in fields**
9. **Identify and apply basic concepts in record keeping.**
10. **Discuss harvest and post harvest management concepts and practices.**
11. **Develop and explain a crop planning budget for a small farm.**

Introduction

In organic crop planning and production farmers must recognize that the whole environment in which plants grow is much more than the sum of its individual parts, and that all living things are inter-related and inter-dependent. Specifically, an organic farmer must understand crop production through the following guidelines:

- Treating the soil and growing environment as a resource to be husbanded for future generations, rather than mined for short term gain.
- Providing plants with a balanced food supply by feeding the many soil living creatures that live with composts, manures and other organic materials.
- Choosing renewable resources, thereby creating a sustainable future.
- Reducing pollution of the environment, by recycling farm and other wastes, rather than dumping or burning them.
- Combating pests and diseases without using pesticides that may prove harmful to human health and that of domestic and wild animals and vegetation.
- Encouraging and protecting wildlife, by creating suitable habitats and by minimizing use of harmful pesticides.
- Creating a safe and pleasant environment in which to work and play.
- Moving with the times—taking new scientific discoveries and ideas into account, as well as the best traditional knowledge.
- Recognizing the importance of genetic diversity and hence the preservation of threatened plant varieties.

Organic Principles

Organic production is not simply the avoidance of conventional chemical inputs, nor is it the substitution of natural inputs for synthetic ones. Organic farmers apply techniques first used thousands of years ago, such as crop rotations and the use of composted animal manures and green manure crops, in ways that are economically sustainable in today's world. In organic production, overall soil, plant and crop system health is emphasized, and the interaction of management practices is the primary concern. Organic producers must comply with several key organic principles in order to be successful organic and sustainable farmers:

Biodiversity

As a general rule, diverse ecosystems in nature have a higher degree of stability than those with only a few species. Farms with a diverse mix of crops have a better chance of supporting beneficial organisms that assist in pollination and pest management. Diversity above ground also suggests diversity in the soil, providing better nutrient cycling, disease suppression, soil tilth, and nitrogen fixation.

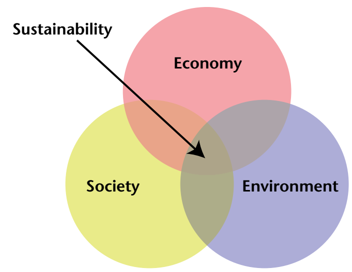
Good organic farmers mimic the biodiversity of nature through practices like intercropping, companion planting, establishment of beneficial habitats, and crop rotation (sometimes referred to as companion planting across time). (Gliessman 2007).

Diversification and Integration of Crop and Animal Systems

The drive to build biodiversity in organic systems encourages diversity among your crops, but not as isolated or independent entities. Good organic operations integrate several cropping systems such as rotations, cover crops, livestock operations that promote soil and water conservation, soil fertility and integrated pest management.

Sustainability

Sustainability and sustainable agriculture consists of integrated, resource-conserving, equitable farming systems based on the understanding of long-term impact of our activities on the environment and on other species. Sustainability is generally considered to incorporate the following principles:



- Meeting the basic needs of all peoples, instead of a few
- Keeping population densities below the carrying capacity of the region
- Adjusting consumption patterns and the design and management of systems to permit the renewal of renewable resources
- Conserving, recycling, and reusing nonrenewable resources
- Keeping environmental impact below required levels to allow the systems affected to recover and continue to evolve. (Gliessman 2007).

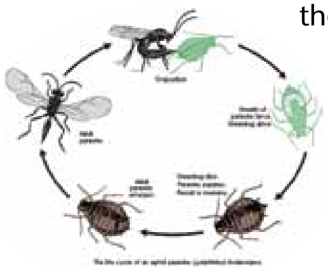
Natural Plant Nutrition

The organic philosophy of crop nutrition begins with proper care and nourishment of the organisms responsible for the soil digestive process, which is done by introducing healthy amounts of organic matter into the soil and avoiding toxic chemicals and practices—like excessive tillage and harmful pesticides—that are harmful to soil organisms. Conventional systems, by contrast, are more dependent on soluble fertilizers to feed their plants. From the organic perspective, the conventional approach has several flaws.

Applying large quantities of fertilizer to a crop only one, two, or three times per season floods the plant with those nutrients, causing nutritional imbalances that lead to crop diseases, insect infestations, and reduced food quality. It can also lead to nutrient leaching when too many nutrients are supplied and irrigation water leaches those nutrients into the groundwater supply. Failure to support and care for soil biotic life, along with other practices that are downright destructive, ultimately leads to its decline. As a result, plants lose out on the nutrients and trace minerals these organisms produce, soil tilth is reduced, and the soil becomes increasingly dependent on synthetic inputs.

Conventional fertilization tends to concentrate on a few macronutrients, even though the need for at least 13 soil minerals is scientifically recognized. This skewed focus is also responsible for generating imbalances in the plant. Application of large amounts of fertilizers can stimulate certain problem weed species. Soluble nutrients—especially nitrate—are prone to leaching, which can cause a number of environmental and health problems.

Natural Pest Management



Whether conventional or organic, all farmers are concerned with pests. They spend a lot of time and resources controlling them. However, in the organic "world view," pests—whether weeds, insects, vertebrate pests, or diseases can ruin the entire cropping system if not controlled.

As scientific understanding has grown, insect pest outbreaks are also being understood as imbalances in the whole agroecosystem and how it is managed. Most organic growers consider pesticides to be a cause of agroecosystem imbalances and employ preventative practices, and secondarily, organically approved pesticides, instead of synthetics, as much as possible.

Integrity

Integrity refers to the systems in place and actions undertaken to assure that consumers of organic products get what they pay for. Consumers have a right to expect that the organic food they buy not only be raised utilizing organic methods, but also be protected from drift contamination and commingling with non-organic products.

While the responsibility for much of this rests with others in the organic marketing/value chain, many certified organic growers need to incorporate additional practices that work to ensure the integrity of their products. Proper record keeping is very important in this regard, though growers are often reluctant to spend much time on it. (Gliessman 2007).

Learn more about Organic Agriculture

Definition of Organic Agriculture International Federation of Organic Agriculture Movements (IFOAM), http://www.ifoam.org/organic_facts/doa/index.html
Sustainable Agriculture: Definitions and Terms, by Mary V. Gold USDA, NAL, Alternative Farming Systems Information Center,1999. http://www.nal.usda.gov/afsic/AFSIC_pubs/srb9902.htm
OrganicAgInfo http://www.organicaginfo.org

Crop Planning & Selection

Modern cropping systems are complex and consist of highly integrated crop planning and production management strategies. Crop planning strategies in today's organic market require farmers to consider many production factors such as global climate change, ground water quality, and nutrient management, as well as food safety and quality, and impacts from invasive species, as they greatly influence crop planning, production and profitability. Pest control systems, cover crops, rotations, tillage systems, buffers and borders, and integration and coordination of inputs for single or multiple crops require well designed crop plans and optimization for continued utility in production systems. In addition, these planning objectives must be combined in new ways to address the needs of small, intermediate, and large-scale farms, organic production, and production in controlled environments such as greenhouses.

Crop Selection

Crop selection is the first step in crop planning. Have you decided what crops are right for your farm? Here are a few things to consider when choosing crops:

1. *Season/climate*: When do your selected crops grow? What crops grow best in our climate? Know if the crop likes cooler or warmer seasons, prefer long day/short days, or are they a year round crop?

2. *The Market:* Consider market demand. Can you sell your selected crops in the marketplace? Will you be able to get a decent price? Do you know where you will sell your product? It is always important to have a complete marketing plan before you plant your crops.

3. *Labor needs:* Who will be available to help you grow and sell your selected crops? When will they be available? How much work will they be willing to do? Will you have enough help to maintain a healthy crop? (Examples: fresh fruits = high labor need, cereal crops = low).

4. *Other Production Costs:* Will you be able to make a profit from your selected crops when considering other resource inputs, certification fees, equipment needed, irrigation, and overall management costs?

5. *Pest susceptibility:* Are your selected crops prone to major pests and diseases? Are there outbreaks of certain pests in the area? If there are, choose a crop that will not be greatly affected.

6. *Companion planting:* Do your selected crops grow well when planted with other crops or do they have an antagonistic or negative relationship? (Examples: corn-beans-squash, or lettuce-carrots-radishes do well together, onions cropped with beans or peas will not fare well).

7. *Crop Rotation:* Do you know the ideal crop rotation for your selected crops? This is very important to know for pest, weed, and disease control as well as soil fertility building.

8. *Soil Fertility:* What soil do your crops prefer? Will your selected crops be influenced by specific salt levels, soil texture, seasonal flooding, quantity and quality of irrigation water?

9. *Erosion:* Do you need crops that fight against erosion? Perennial crops, for example, planted on steep slopes will help reduce erosion problems.

10. *Personal preference:* Take all of these into consideration but grow something that you enjoy and with which you have experience, or would like to develop expertise!

Exercise: Crop Plan Creation

1. Make a field plan for a theoretical half acre. Show which crops you would plant in each row. Explain your choices and what you took into consideration in making your choices.
2. Group and rank 10 common vegetables according to: (1) Adaptability (2) Labor (3) Selling price (4) Personal consumption (5) Economic return

Example:
adaptable: radish
labor: potatoes need to be dug by hand
selling price: organic strawberries $20/box
personal consumption: children like strawberries
economic returns: shallots are in high demand and sell well.

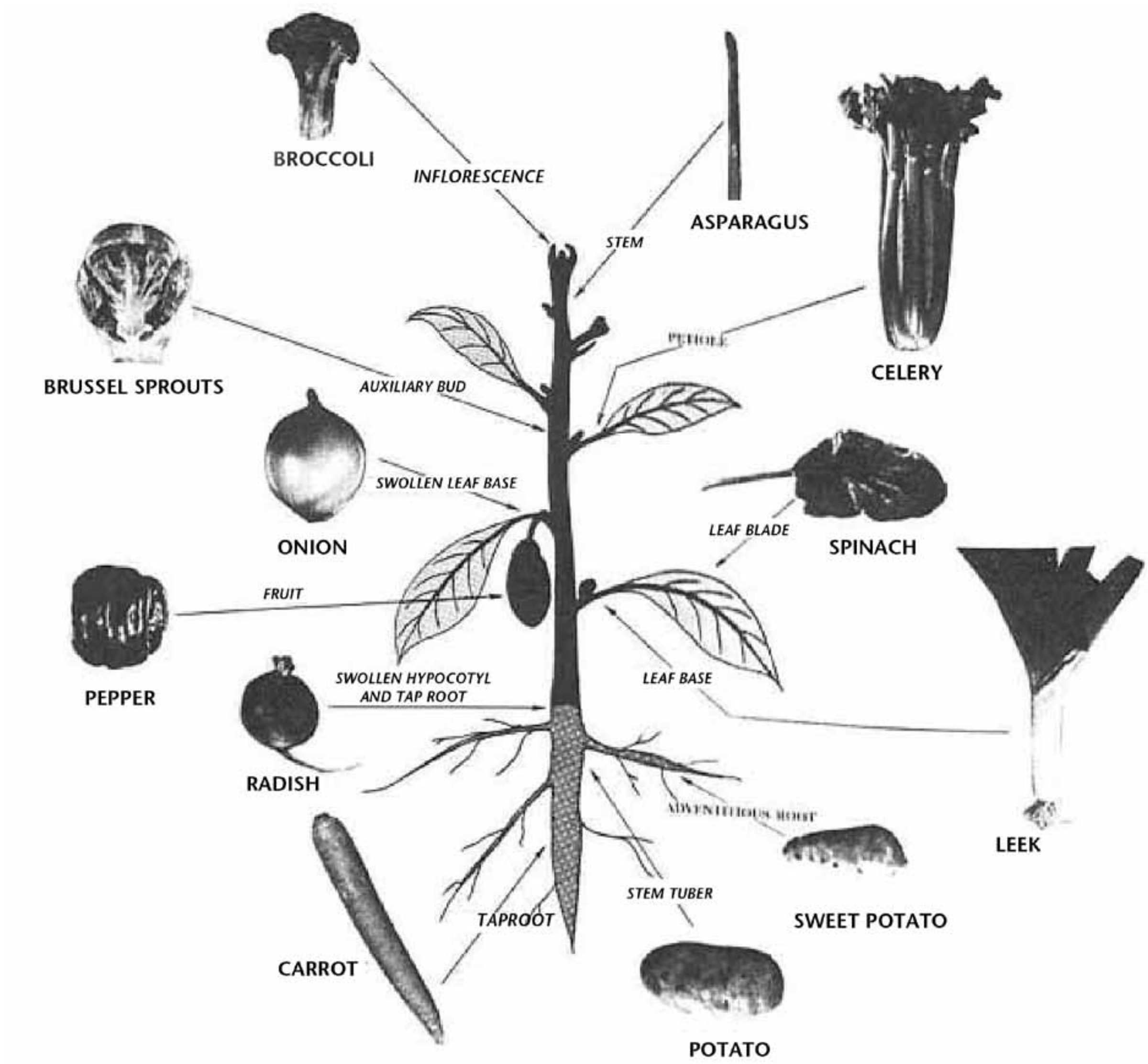
   1. Adaptability:
   2. Labor:
   3. Selling price:
   4. Personal consumption:
   5. Economic return:

   List any competing interests and overlaps between the factors.

3. Visit a fresh market and a supermarket and compare whether your crops can be grown locally.

Basic Botany

It's important to know the plant you are growing, its functions, and which plant parts are harvested and sold at the market.



Plant Parts

Roots

- Most roots grow in soil or water.
- Roots hold the plant in the ground—serving as a substrate.
- A plant uses its roots to get water.
- The water goes through the roots into the plant.
- Some roots that we eat are: *carrots, beets, turnips, radishes, and sweet potatoes.*

Stems

- Part of the plant between the roots and the leaves
- Holds up the plant.
- Carries water and food to other parts of the plant.
- Some stems that we eat are: *broccoli, asparagus, white potato*

Leaves

- Grow on the stem or branch of a plant.
- Makes food in its leaves through PHOTOSYNTHESIS
- Has tiny holes that let water vapor and air pass through.
- Need sunlight, air, and water to make the food for the plant.
- Some leaves that we eat are: *lettuce, Brussels sprouts, spinach, and parsley.*

PHOTOSYNTHESIS is the process in which plants convert sunlight into food energy. This takes place in the green leaves. From sunlight energy, green plants combine carbon dioxide and water to make sugar and oxygen.

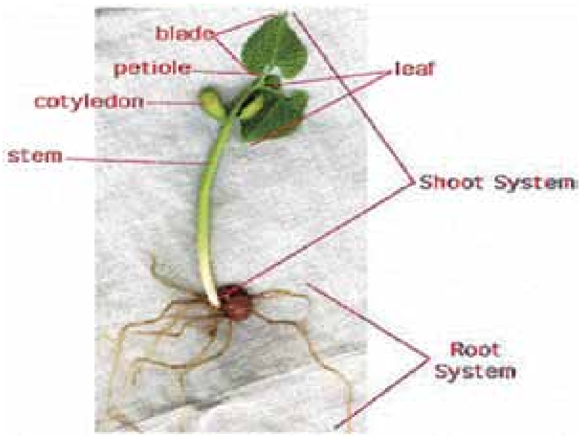
Flowers, Fruits and Seeds

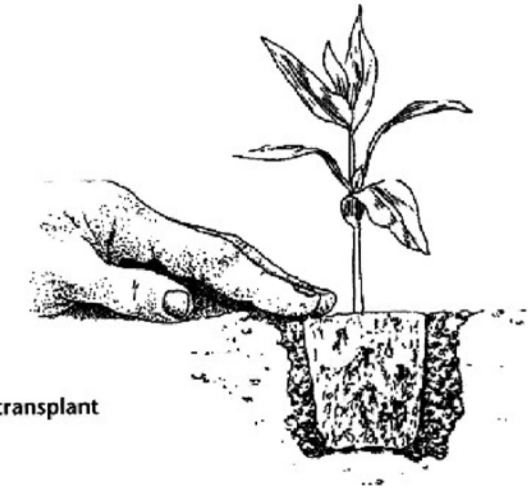
- Grow on the stem of plants.
- Flowers make seeds. Many plants grow from seeds.
- Flowers make fruits. Fruits hold the seeds of the plant.
- Some fruits that we eat are: *tomatoes, oranges, watermelon, and strawberries.*

Tuber and Bulbs

- Both function as a storage organ, so they are similar in some ways. A tuber, however, just stores nutrients, whereas a bulb is a self-contained plant.
- Some are heartier than others: some can stay in the ground; some must be dug up, although all are considered perennials.
- Choose a large, plump bulb or tuber—the larger the storage organ, generally the larger the bloom!
- Some tubers are *potatoes and yams.* Some bulbs are *onions, shallots and garlic.*

Plant Life Cycle





Seeds are small, usually round (but not always) and contain the plant embryo and stored nutrients. A seed is planted directly in the soil or in transplanting trays in the greenhouse. Seeds need soil, water and optimal temperatures for germination. The soil provides a substrate for the seed to germinate in—but many seeds can germinate without soil, in a growing medium like vermiculite or just in a paper towel. Seeds need *constant* moisture to germinate well and most seeds have to reach an optimal *soil* temperature at which they will germinate.

Embryos are young plants present in the seed before germination.

Seedlings are young plants after germination.

Transplants are established seedlings that have been started in the greenhouse, then later moved to the field and planted in the ground. Seedlings may become transplants when 2–3 sets of true leaves appear and plants are 4–7 inches in height. Transplants usually require lower air temperatures than seeds to grow once they have germinated. Transplants need less water than seeds once germinated.

Plant Types: Annuals and Perennials

Annuals complete their life cycle in one growing season. Seed germinates in the spring, the plant grows, flowers, produces seed and then dies during one growing season. Examples are tomatoes, cucumbers, and pumpkins.

Perennials live for more than one growing season. There are two types of perennials. Herbaceous perennials generally die to the ground at the end of the growing season but send up new shoots the following spring such as strawberries and artichokes. Woody perennials, such as trees and shrubs, do not die back to the ground but tend to get larger each year.

Biennials are flowering plants that take two years to complete their biological lifecycle. In the first year the plant grows leaves, stems, and roots (vegetative structures), then it enters a period of dormancy over the colder months. Usually the stem remains very short and the leaves are low to the ground, forming a rosette. Many biennials require a cold treatment, or vernalization, before they will flower. During the next spring or summer, the stem of the biennial plant elongates greatly, or "bolts." The plant then flowers, producing fruits and seeds before it finally dies. There are far fewer biennials than either perennial plants or annual plants. Examples of biennial plants are parsley, Lunaria, silverbeet, Sweet William, colic weed, and carrot. Plant breeders have produced annual cultivars of several biennials that will flower the first year from seed, e.g. foxglove and stock.

Timing of Planting

Planting times for vegetables and other annual plants vary from species to species. The prime planting consideration is the date of the last spring frost/freeze and first fall frost/freeze. Many vegetables can be planted up to four weeks before the last frost, while others need to wait until a couple of weeks after the frost. By understanding the times and length of frost free weather in your area you can have a better chance for success in your vegetable garden.

Very Cold Tolerant Plant as soon as ground can be worked, somewhat?	**Somewhat Cold Tolerant** Plant 2–4 weeks before the first average frost-free date.	**Frost Sensitive** Plant after the last frost
Asparagus	Beets	Melons
Horseradish	Broccoli	Peppers
Leeks	Cabbage & Kohlrabi	Tomatoes
Onions	Carrots	Sweet Corn
Parsnips	Cauliflower	Eggplant
Peas	Celery	Cucumbers
Spinach	Collards	Artichoke
Turnips	Lettuce, Kale, Endive	Squash

Many vegetable plants that are planted in the spring can be planted again towards the end of the season. Some vegetables and fruits, such as winter squashes and some melon varieties, seem to do better when planted in the warmer months and others, such as broccoli in cooler months. Some crops are short and long season varieties. Review the Families of the Day section of this manual for ideal soil temperatures for germination of crops of interest. You can also contact your local Agricultural Commissioner's Office on the right months to plant your crops in your area.

Types of Cropping Systems

There are a variety of cropping systems that a farmer can choose in his or her crop production plan. The main factor to remember when choosing the right cropping systems for your farm is to keep it diverse. It is important to implement a variety of different cropping systems into your plan that promote many ecologically environments. For many small farmers this is key when choosing to grow and sell organic crops. Here are major cropping systems you will need to think about when constructing your crop production plan:

Intercropping system (companion planting): Planting two or more crops together in a single field.


Strip intercropping system

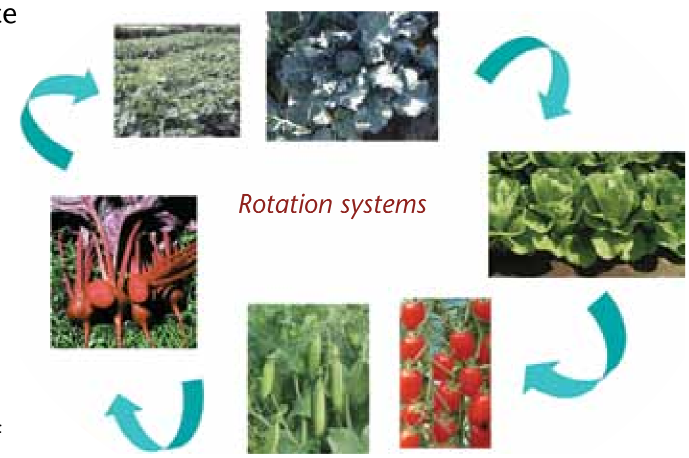
Strip intercropping system: Planting a single crop in one row and then a different crop in the next row or strip.

Hedgerows/ Buffer Vegetation system: Planting trees or shrubs around the perimeter of fields, along pathways of a farm, or to mark boundaries. They can provide protection from the wind, can produce an array of tree products, and serve as habitat for birds and other wildlife


Cover cropping system

Cover cropping system: Planting a crop species from which you do not intend to harvest a commodity in order to cover the fields in between cropping cycles and to provide soil cover. Cover crops enhance soil organic matter, stimulate soil biological activity and diversity of the soil organisms, trap nutrients in the soil, reduce soil erosion, increase soil nitrogen, and provide an alternate host for beneficial insects. Popular cover crops include a number of annual legumes and cereal crops (2007 Gliessman).

Rotation systems: Planting different crops one season after another or in "succession" in a particular field year after year. As crops grow they introduce chemicals into the soil that can either produce a positive or negative effect on the crops that are grown in the same spot next season. Therefore, knowing which crops to grow in rotational cycles can help guard against pest, disease and even common weed problems. Crop rotation can also improve soil fertility, reduce soil erosion and maintain soil organic matter. A common crop rotation is beans one year and corn the following year. The corn takes advantage of the additional nitrogen in the soil after the bean crop.


Rotation systems

Fallow cropping system: Land is fallow when the soil is kept bare for a period, and not even weeds are allowed to grow; can be done with herbicides, or via frequent cultivation.


Fallow cropping system


Reduced or Minimum tillage system

Reduced or Minimum tillage system: Reducing the intensity of soil cultivation and leaving residues on the surface with little disturbance to the soil. This system can increase earthworm abundance and activity, organic matter, nutrient holding capacity and cycling, and improve soil structure.

High Organic Matter Input system: Introducing composts, incorporating crop residues into the soil, cover cropping, diversifying crops, biofertilizers, etc.

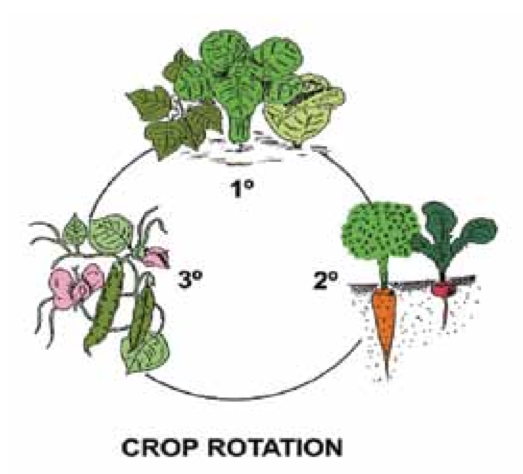

High Organic Matter Input system

Integration of Livestock and pollinators systems: Integrating animals and bees into the production field. Grazing, trampling, scratching, and manure deposits from pigs, chickens, sheep, goats and cattle can alter aspects of the soil structure and fertility. Bee pollination can also help increase seed production and overall crop yields.


Integration of Livestock and pollinators systems

Crop Rotation

Crop rotation is a cropping system method that is based on alternating crop families grown in a given field from one growing season to the next. This is done because the alternating crops take different nutrients from the soil, or because one crop might restore particular nutrients that the other one takes away. Crop rotation can also interrupt the life cycles of pests or plant diseases that prey on a particular crop. The following is a common 3-year rotation cycle of (1) a leafy crop (2) a root crop to increase aeration of the soil (3) and a nitrogen fixing legume to improve soil fertility.



The following is an example of a 5-year rotational cycle by crop families:

Family	Sequence Examples	Soil requirements	Soil benefits
Brassicas	Cabbage, cauliflower, radish, broccoli	Leafy crops need nitrogen-rich soil; may need liming	Radish breaks up soil structure
Legumes	Pea, bean (broad, French and runner)	Well-drained but moisture-retentive; not nitrogen-rich	Fix nitrogen in roots for future crops, provides organic matter
Alliums	Onion, garlic, shallot, leek	High organic matter; may need liming	Increase pest and disease resistance of adjacent crops
Solanacea	Potato, tomato	High organic matter and nitrogen (potato); no lime	Suppress weeds, break up soil structure
Umbellifers	Carrot, parsnip, parsley, celery, Florence fennel	Root crops need stone-free soil; not freshly manured; fine tilth	Root crops break up soil structure

Year one: As above
Year two: Legumes, Solanacea, umbellifers, brassicas
Year three: Alliums, Solanacea, umbellifers, brassicas, legumes
Year four: Solanacea, umbellifers, brassicas, legumes, alliums
Year five: Umbellifers, brassicas, legumes, alliums, Solanacea

Some plants have so few soil-dwelling pests or diseases that they can be fitted in any where in the rotation: Fennel, chicory, cucumbers, endive, beans, lettuce, marrows, peppers, pumpkins, squashes, sweet corn.

Exercise: Crop Rotation
In the box below, write 4 different crop rotations for your first year of production:

Fall	Winter	Spring	Summer

Intercropping and Companion Planting

Agronomists use the term "intercropping" to describe the spatial arrangements of companion planting systems. Intercropping systems range from mixed intercropping to large-scale strip intercropping. Mixed intercropping is commonly seen in traditional gardens where two or more crops are grown together without a distinct row formation.

"Companion planting" can be described as the establishment of two or more plant species in close proximity so that some cultural benefit (pest control, higher yield, etc.) is derived. The concept embraces a number of strategies that increase the biodiversity of agroecosystems.

Traditional Corn-Bean-Squash Intercropping

This has been traditionally practiced throughout Central America in order to optimize the available resources required to grow the crops.

Corn grows high and provides a natural support structure for the beanstalks to climb. Squash absorbs light between the corn rows to grow along the ground. Squash provide shade on the ground and hinder weed growth.

Beneficial Habitats

- Beneficial Habitats – companion plants provide a desirable environment for beneficial insects and other arthropods—especially those predatory and parasitic species which help to keep pest populations in check.
  Predators include ladybird beetles, lacewings, hover flies, mantids, robber flies, and non-insects such as spiders and predatory mites.
- Trap Cropping – a companion crop may be selected because it is more attractive to pests and serves to distract them from the main crop. An excellent example of this is the use of collards to draw the diamond back moth away from cabbage. Often a vacuum is employed to remove those pests from the trap crop without damaging the commercial crop.
- Symbiotic Nitrogen Fixation – Legumes—such as peas, beans, and clover—have the ability to fix atmospheric nitrogen for their own use and via symbiotic relationship with Rhizobium bacteria. Forage legumes, for example, are commonly seeded with grasses and vegetables crops such as corn to reduce the need for nitrogen fertilizer.
- Biochemical Pest Suppression – some plants exude chemicals from roots or aerial parts that suppress or repel pests and protect neighboring plants. The African marigold, for example, releases thiopene—a nematode repellent—making it a good companion for a number of garden crops.
- Physical Spatial Interactions – tall-growing, sun-loving plants may share space with lower-growing, shade-tolerant species, resulting in higher total yields from the land. Spatial interaction can also yield pest control benefits.
- Nurse Cropping – Tall or dense-canopied plants may protect more vulnerable species through shading or by providing a windbreak. Nurse crops such as oats have long been used to help establish alfalfa and other forages by supplanting the more competitive weeds that would otherwise grow in their place. Similarly with vegetable crops, taller growing crops could be planted next to cilantro to keep it from bolting in the summertime heat.
- Security through Diversity – a more general mixing of various crops and varieties provides a degree of security to the grower. If pests or adverse conditions reduce or destroy a single crop or cultivar, others remain to produce some level of yield (Kuepper & Dodson 2001).

Companion Planting (Kuepper & Dodson 2001).		
Crop	**Good companion**	**Bad companion**
Asparagus	Tomato, parsley, basil	
Beans	Most vegetables and herbs	
Bean, bush	Irish potato, cucumber, corn, strawberry, celery, summer savory, radish	Onion, beet, kol
Beans, Pole	Corn, Summer Savory, Radish	Onion, Beets, Kohlrabi, Sunflower
Cabbage Family	Aromatic Herbs, Celery, Beets, Onion Family, Chamomile, Spinach, Chard	Dill, Strawberries, Pole Beans, Tomato
Carrots	English Pea, Lettuce, Rosemary, Onion Family, Sage, Tomato	Dill
Celery	Onion & Cabbage Families, Tomato, Bush Beans, Nasturtium	
Corn	Irish Potato, Beans, English Pea, Pumpkin, Cucumber, Squash	Tomato
Cucumber	Beans, Corn, English Pea, Sunflowers, Radish	Irish Potato, Aromatic Herbs
Eggplant	Beans, Marigold	
Lettuce	Carrot, Radish, Strawberry, Cucumber	
Onion Family	Beets, Carrot, Lettuce, Cabbage Family, Summer Savory	Beans, English Peas
Parsley	Tomato, Asparagus	
Pea, English	Carrots, Radish, Turnip, Cucumber, Corn, Beans	Onion Family, Gladiolus, Irish Potato
Potato, Irish	Beans, Corn, Cabbage Family, Marigolds, Horseradish	Pumpkin, Squash, Tomato, Cucumber, Sunflower
Pumpkins	Corn, Marigold	Irish Potato
Radish	English Pea, Nasturtium, Lettuce, Cucumber	Hyssop
Spinach	Strawberry, Fava Bean	Irish Potato
Tomato	Nasturtium, Corn, Marigold	Irish Potato, Fennel, Cabbage Family

Cover Cropping

A cover crop is a crop planted in a field to protect the soil from erosion and to improve the soil by adding organic matter. Most farmers use a cover crop in the winter when the fields are not planted with vegetables; however it can be done in the summer when you have a short break between crop successions.

Cover crops can be divided into two groups: legumes and non-legumes (see table). Legumes have the ability to "fix" nitrogen and can provide a portion of the nitrogen requirement for a subsequent crop. Within these two groups are both warm-and cool-season species that can be successfully grown in the cropping fields. Cool-season legumes include Austrian winter peas and vetch. Warm-season legumes include all of the southern peas and the common beans. Cool-season non-legumes include the cereals oats, wheat, rye and barley. Warm-season non-legumes include buckwheat and sudan grass.

Proper use of cover crops will improve the overall productivity of the soil. While the cover crop is growing, it will help prevent soil erosion and assist in weed control. The organic matter provided when a cover crop is plowed under will improve soil structure and aeration, water and nutrient-holding capacity and supply a portion of the nutrient requirements for subsequent crops. The type of cover crop growing and the length of time it is growing will determine how much organic matter and nutrients will be returned to the soil. A legume may provide more nitrogen but less total organic matter than a vigorously growing non-legume like rye. As a group, legumes are more likely to harbor virus diseases and allow some soil-borne diseases to survive than most non-legumes. They also do not provide as much weed suppression as the cereal crops. However, the advantages of the nutrition provided by legumes may more than offset this disadvantage.

Exercise: Compare and Contrast Cover Crops

In the following chart, compare the effects and the sowing times for legumes and non-legume cover crops.

Type	Legume/ Non -legume	When to Sow	When to Turn Under	Effects	Notes
Alfalfa (*Medicago sativa*)	L	Spring/ Late Summer	Fall/Spring	Fixes 3–6 lb N/1000 sq ft/yr; deep roots break up hard, compacted soil.	Loam, fairly fertile soil; needs warm temperatures for germination; lime if pH is low; hardy; drought-tolerant; inoculate.
Barley (*Hordeum vulgare*)	N	Fall/ Spring	Spring/Fall	Adds organic matter, improves soil structure.	Prefers medium-rich loam soil; lime if pH is low; not as hardy as rye; tolerates drought.
Buckwheat (*Fagopyron esculentum*)	N	Spring/ Summer	Summer/ Fall	Mellows soil; rich in potassium.	Must leave part of garden in cover crop during growing season; grows quickly; not hardy.
Crimson clover (*Trifolium incarnatum*)	L	Spring/ Fall	Fall/Spring	Fixes 2–3 lb N/1000 sq ft/yr.	Not reliably hardy or drought-tolerant; lime if pH is low.
Fava beans (*Vicia faba*)	L	Early Spring/ Late Summer	Early Summer/ Fall	Some types fix 1½–2 lb N/1000 sq ft in as little as 6 weeks. Use small-seed rather than large-seed table types.	Will grow on many soil types; medium drought tolerance; likes cool weather. Inoculate with bacteria as for other legumes.
Oats (*Avena sativa*)	N	Spring/Fall	Summer/ Spring	Adds organic matter, improves soil structure.	Not hardy; tolerates low pH.
Rye, annual (*Lolium multiflorum*)	N	Fall/Spring	Spring	Adds organic matter, improves soil structure.	Very hardy; can plant until late fall/early winter.
Vetch, hairy (*Vicia vellosa*)	L	Early Fall	Spring	Fixes 2 lb N/1000 sq ft/yr.	Slow to establish; fairly hardy; till under before it seeds; can become a weed; inoculate seed before planting.
Wheat, winter (*Triticum aestivum*)	N	Fall	Spring	Adds organic matter,improves soil structure.	Same as barley.

From: *Market News*. March 2005

Successive Planting

Successive planting is the process of scheduling crops in order to produce a continuous harvest each week. Farmers conduct successive planting by planting crops every two-three week interval, or at monthly intervals to ensure that a harvestable crop will be ready each week for the market. Successive plantings are planned while considering the following four factors:

- Selling period – Growers have to decide the best times to sell their crops. Experienced growers have a pretty good idea about the beginning and the end of the peak selling period for direct and indirect markets. For most direct markets such as farmer's markets, for example, the peak selling period is during the warmer months in May to late September. If you want to participate in weekly farmers markets or a weekly CSA business during these months, you will need to plant your crops in successive plantings in the early spring through early August in order to harvest crops each week during the optimal selling period. It is also a good strategy to have certain crops when others don't, such as early or late in the season. Prices tend to be higher at those times. This can be achieved through various season extension strategies, such as early transplanting, high tunnels, floating row covers, etc.
- Annual frost free days – Another common way to schedule crops is to plan around the average annual frost-free date in the spring and the average annual first-freeze date in the fall.
- Optimal soil temperature for germination and optimal planting temperatures for plant growth – Planning your crops in accordance with optimal soil temperature for germination and optimal planting temperatures for vegetables are other ways to schedule your plantings.
- Optimal times for insect and disease infestation – Insect and disease occurrence is another major factor affecting successive plantings. It is important to know what major pests and diseases affect your crops when outbreaks occur. You can then plan to plant before or after major infestations to protect your crop.

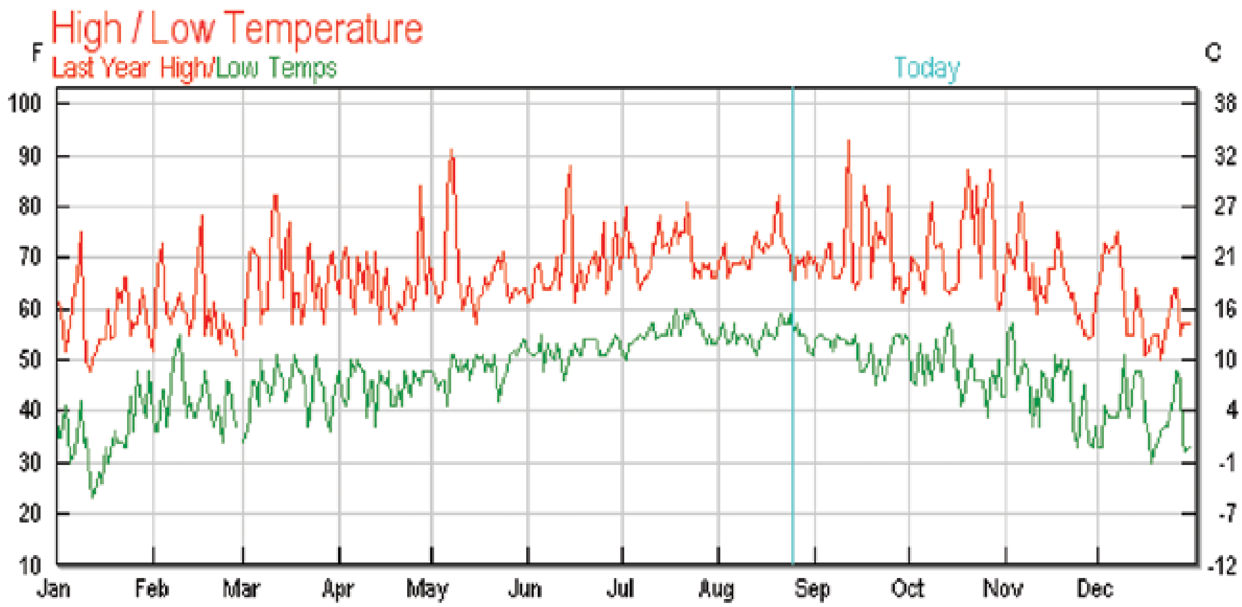
Exercise: Optimal Temperature for Plant Growth

In the boxes below, please identify the optimal temperature for plant growth for 5 different vegetables. Place the names of the crops and the optimal soil temperature in the appropriate month for that temperature.

Optimal Temperature for Plant Growth

Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec

To help you complete this activity, please review your **Families of the Day** section in this manual for optimal temperatures for your crops. You may also determine the best months to plant your crops by reviewing the following report of average monthly High/ Low Temperatures for Salinas in 2006.



Weather Underground (2008)

Planting Depth

Seeds planted too deeply take longer to come up, if they come up at all. Also, weeds may grow up first and crowd out vegetable plants. Conversely, shallow seeds may wash away or dry out before they sprout.

As a rule, plant vegetables with small seeds—such as cabbage, carrots, radishes, and lettuce—0.5 inch deep. Plant vegetables with medium-sized seeds—such as beets and chard—0.75 inch deep. Plant large-seeded vegetables—such as beans, corn, and squash—1 to 1.5 inches deep. Most seed catalogues will provide the correct spacing for the crops you select.

Planting Distance

Correct spacing allows each plant to get its share of sunshine, water, and soil nutrients. If you plant seedlings too close to each other, the vegetables will not grow as large as they normally would and could increase disease pressure from inadequate air flow. Be sure you follow the correct plant and row spacing requirements for each crop you plant. This information is available in your seed catalogues and vegetable crop resource guides.

Seeding Rates for Direct Seeding and Transplants

When you want to know how much seed to plant for each of your crops, you should consider the following criteria: (1) Desired yield of the plants, which depends on the (2) Area of production (3) Spatial arrangement (within-row and between-row spacing) (4) Percent germination (5) Specific variety to be planted, (6) Relative size desired for harvested product, (7) Suitability of the growing season for that population, and (8) Disease and insect considerations.

1. **Plant yield** – Seeding rates should generally be lower for transplants; when you want to plant larger seeds like pumpkins and melons; when you want lower yields to produce larger fruits and crops; and in areas of limited rainfall. Higher seeding rates are more common in direct seeding; when you want higher yields and hasten crop maturity; and in areas where moisture is plentiful throughout the growing season. You can also increase the seeding rates if you plan to harvest the thinnings, such as baby carrots, to allow every other carrot to grow to normal size. Or if your market is for beet greens and not the beet roots themselves, you can plant much more densely.
2. **Area of production** – The length and width of your production area is key in knowing how much seed will be planted. This will allow computation of the area of your field in square feet, which will help you calculate more accurate seeding rates for your crops.
3. **Planting space between plants and rows** – Plants of a given vegetable variety require a specific planting space between plants and between rows in order to receive an "optimum" amount of water, nutrients, sunlight under a given set of growing conditions. An ideal spatial arrangement is to plant crops equidistant from each other.
4. **Percent germination** – Only a portion of the seed (usually from 70% to 90%) in a given seed package will germinate. Percent germination is determined by testing a specific amount of seed for its average percent germination. Percent germination calculation should be shown on any packaged seed label. Always check this label to confirm the percent of seed expected to germinate. If there is any doubt about the percent germination, a germination test should be done before planting the seed. Contact your local county extension office if you need instructions for conducting a germination test. A simple method is to just lay 100 seeds on a wet paper towel, keep moist, and count how many of those 100 seeds germinate after a week or so to record percent germination.

   When determining seeding rates, growers compensate for less than 100 percent germination by including "extra seed." Calculating in 25-30% additional seed can significantly increase the amount of seed a grower needs to plant to obtain the desired population. This may not be ideal if the seed is expensive or if thinning the crop down to the desired density will be too labor intensive for you.
5. **Plant variety** – Crops come in all shapes and sizes. Crops can be highly vigorous vegetable varieties (cultivars) that will grow faster and become larger than less vigorous ones. Larger plants need more space than smaller plants. As a general rule, varieties that produce larger plants should not be seeded at the higher populations suitable for smaller plants. Sometimes, high populations of vigorous varieties are planted to prevent the harvestable plant part (head of cabbage, ear of corn, etc.) from reaching its maximum size.
6. **Desired size of harvested plant part –** Identical varieties can produce larger or smaller sized produce (heads, fruits, roots, tubers or leaves) depending on the number of plants per acre. In fact, increasing the seeding rate is a cultural practice routinely used to help

decrease the size of many vegetables including watermelon, cantaloupe, cabbage, broccoli and sweet corn.

7. **Suitability of the growing season –** Most vegetables respond to a more favorable growing environment (especially warmer, growth-enhancing temperatures and increased sunlight) by growing more vigorously. During less favorable production seasons (especially early spring and early fall), yields can often be increased by increasing the seeding rate.
8. **Pest and disease resistance –** Dense plant populations created by a high seeding rate may provide an environment that predisposes certain vegetable crops to insect and disease damage. Often dense plant populations may create high humidity, moisture and reduced air movement that may encourage many foliar diseases (excluding soil-borne diseases) that cannot be satisfactorily controlled by currently available organic chemical and biological control measures. Dense canopies also make it difficult for pesticides to cover the entire plant.

Seeding Rate Calculations:

Let's say you are asked to calculate the plant density for one row of carrot plants. The single row is 300 ft long and 42 inch wide. Observe plant density for carrots in a local seed catalogue and determine the following information: (1) Number of seeds planted per 1 ft., (2) Planting space between plants, (3) Planting space between rows, (4) Number of lines planted per row. What is the seeding rate for carrots for one row?

How would you calculate the seeding rate for carrots? Answer:

Length of row = 300 ft
Width = 42 in.
Number of seeds per foot = 30 (you must know the spacing between plants and rows)
Number of planting lines per row = 3 (in a row width of 42 in. lines will be 14 in. apart)
Number of rows = 1

Calculations = 30 x 3 x 1 x 300 = 27,000 seeds for 300 ft row of carrots

Site Selection and Bed Preparation

Site Selection

The ideal location also should provide wind protection. Springtime winds are notorious for snapping the tender stems of young plants. Summer winds increase water use by plants and, under severe conditions, dry out or desiccate foliage. A border of shrubs is effective in reducing wind speed, as are various types of fences. Natural windbreaks such as tress and bushes, or artificial windbreaks such as barrier fencing used around construction sites, reduce wind speed and decrease plant stress, which helps farmers produce greater yields.

Locate your farming plot near a water source. Although raised bed gardening offers many advantages, beds tend to dry out more quickly because of their elevation. Consequently, irrigation is mandatory. Consult the chapter on drip irrigation for information on installing a drip irrigation system in the raised bed garden.

Bed Preparation

For most row crops, seeds and transplants are planted in raised beds. Raised beds have the following benefits:

- *Improved drainage.* This is the chief reason raised beds are utilized. Helps avoid flooding of crops after heavy rains. Poorly drained soils tend to be oxygen deficient. Consequently, growth and development is impeded, and production potential is seldom achieved. Raising the soil above ground level allows excess moisture to drain out. As gravitational water moves out, air (oxygen) moves in. Plant roots require oxygen to function. This is why waterlogged plants fail to grow and even die if the poor drainage situation persists.
- *Higher yields with wider rows.* Because plants are uniformly spaced over the surface of a wide bed as opposed to single rows separated by pathways, a high plant density can be realized. This translates into increased yield per square foot of garden space.
- *Extended season.* Raised beds heat up earlier in the spring. Because of their height, they intercept more of the sun's rays in late winter and early spring. This phenomenon permits earlier seeding and transplanting. Plants also grow faster once they are established.
- *Ease of labor.* Raised beds make harvesting and hand-weeding easier on your workers. They can increase their speed while easing strain on their backs.

Farm Equipment and Techniques Used in Bed Preparation and Weed Management

1) Soil preparation prior to bed formation

- Wait until cover crops begin to flower or two weeks before planting to prepare your beds.
- Mow the cover crop with a flail mower and incorporate immediately with a spader or disc.
- Wait two weeks or so for the cover crops to decompose in the soil.

2) Bed spacing

- Bedded rows should be spaced on 5ft or 6ft centers depending on the equipment. A bed width of 40 inch should slope from the center to the edge with a drop of 1.25 inches, allowing excess rainfall to run off. (2001, Sanders).

3) Forming beds & mechanized bed forming tools

- After two weeks or when cover crops have decomposed, use a cultivator or spader with bed shaping panels to form your beds. The bed shaper has flat metal panels that rub against the top and sides of the bed, working the soil surface just enough to disrupt germinating weeds. You can also use a bed shaper for bedding machines in single and multiple row models.
- With some bedding machines, the soil is lifted and then bedded in one operation. With others, the soil is first lifted in one operation with hilling disks or double disk hillers on a tool bar and then compressed to a uniform height and density using a bed press pan. ***Note:*** Be sure that enough soil is pulled up so that the bed has good sharp corners.

- If beds are well-shaped but you can see developed weeds and grasses, add ranks of **S-tine shanks** with 1- to 2-inch shovels over each bed.
- Place S-tines ahead of the shaper and use a row of bed-firming straight minicoulters behind it to prepare the bed for planting

4) Guidance for planting in straight lines

- Setting out string between two stakes at the appropriate distance at each end of the row to help keep your lines straight for planting.

5) Rolling cultivators for weed management

- Rolling cultivators cut and tear weeds from the soil. Cultivators have a light ridging effect toward the row but are not as damaging to soil structure as a rototiller. The angle at which the cultivator units operate is hydraulically adjusted from the tractor seat. This is to avoid covering plants from the upper side of the row. This type of cultivator works in a no-till situation moving through moderate plant debris without clogging. Two heavy s-tines loosen soil behind the tractor wheels. Many adjustments allow for cultivating narrow rows and those up to a width of 48".

6) Cultivator blades and shovels

- Foot Sweep Cultivator Blades, MB Plough Blades, Moisture Mulcher Blades, Reversible Cultivator Shovels and Rotary Tiller Blades, Seed Drill Shovel, Power tiller Blades, Rototiller Blades

***DO NOT** WALK ON BEDS DURING THE GROWING SEASON!!*

Once constructed, beds are never walked on during the growing season. In traditional fields, walking on the top of beds can compact the soil, often in close proximity to the plants. Plant roots struggle to penetrate compacted soil. Water and oxygen move more slowly in compacted soil. Surface tillage cannot alleviate compaction at a lower depth.

Larger conventional farms where tractors and other equipment will be used in vegetable production often rely on clean cultivation where the entire previous crop residue has been worked deep into the soil, often resulting in a soil virtually free of crop residues. A smooth, debris-free bed is ideal for direct seeding where precision of seed placement is critical. The disadvantage of clean cultivation is that organic matter is lost more quickly with such preparation. In most cases this will require the addition of organic matter annually in order to see a benefit (Roberts 2007). By utilizing a flail mower on your cover crops or previous crops to chop the organic materials finely and then quickly incorporating so that microorganisms rapidly break it down, you can achieve a fairly fine seed bed.

Rototilling and/or using a chisel plow is also prone to compaction and the formation of a hardpan from the perpetual plowing to the same depth. Hardpans are nearly impenetrable layers of soil that develop below the surface at the plow depth. These can be difficult to break up and may require the use of a large tractor capable of pulling deep rippers. Deep turning of hardpans can still be an aid to crop performance, although it can bring nutrient poor soil closer to the surface and push the richer soil underneath it.

Season Extension

Season extension is a range of cultural practices that simply "extend" how long you are able to grow a crop during the season. In California, season extension is a highly valued practice as fresh vegetables are in high demand during the winter and early spring when most farmers plant less due to cooler climates that are unfavorable for most crops. Farmer's who use season extension practices benefit economically by selling crops at higher prices during the winter months and early spring when market demand is high for fruits and vegetables. Having produce consistently at the markets also gives farmers the advantage of keeping your customers coming back throughout the season.

Some season extension practices include:

- Greenhouses come in two general types: Solar greenhouses—those that rely on the sun to provide heat and light. Artificially controlled greenhouses—those that use artificial heat and light sources within the greenhouse. In both cases, farmers control the climate within the greenhouse. The difference is in the methods used and the energy consumed to complete the task. But do keep in mind that the Solar greenhouses methods often work best for smaller operations (see more information at the end of this section).
- Row covers – A row cover is simply a piece of cloth that growers use to cover plants for frost protection, inclement weather, chemicals lifted by wind, insect protection, conserving soil moisture, improved seed germination, and season extension. They come in many sizes, thickness and materials. They are cut to fit a row or bed, laid on top of the plants or on hoops, anchored with soil, rocks or other material and they can keep hail, frost, or insects at bay. They are not always easy to handle, especially the first season or two, so knowing which to use and how to use them will require practice (Goodman 2005)
- Biodegradable mulches – Mulches prevent loss of water from the soil by evaporation. Mulches reduce the growth of weeds, when the mulch material itself is weed-free and applied deeply enough to prevent weed germination or to smother existing weeds. Mulches keep the soil cooler in the summer and warmer in the winter, thus maintaining a more even soil temperature. Mulches prevent soil splashing, which not only stops erosion but keeps soil-borne diseases from splashing up onto the plants.

Biodegradable mulches

There are two types of mulches:

- Organic mulch is made of natural substances such as bark, wood chips, leaves, pine needles, or grass clippings and groundcovers. Organic mulches can attract insects, slugs, cutworms and the birds that eat them. They decompose over time and need to be replaced after several years.
- Inorganic mulches are generally made from non-renewable resources such as gravel, pebbles, black plastic and landscape fabrics. Inorganic mulches do not attract pests and they do not decompose.

Organic mulch

- Cold Frame is a construction of four walls to trap heat and shelter plants, and a transparent lid that admits light. These are often used in winter months and are made out of sturdy material—plywood, concrete, even bales of hay. An old window works perfectly as a lid, but you can also use Plexiglas or plastic sheeting tacked to a frame.

  The transparent lid's size usually determines the dimensions of the cold frame. Still, you'll want it to be larger than 2 by 4 feet to make it worth your while; you don't want it much larger than 3 by 6 feet, so that you can reach all the plants inside. Build the back 4 to 6 inches higher than the front to maximize the amount of light that reaches the plants inside and to allow water to drain off the top easily. Since cold frames are so small, they are often used for production of transplants.

Inorganic mulch

Cold frame

- High Tunnels are greenhouse-like structures which modify the climate to create more favorable growing conditions for crops. Many commercially available High Tunnels are on the market in numerous widths, lengths, and arch shapes and are constructed of metal bow frames that are covered with a single layer of polyethylene. Ventilation is achieved by means of a combination of roll-up side vents; end vents; and occasionally, roof vents. They are affordably priced, relatively easy to construct, and can be used in a variety of farm enterprises from winter egg production to summer tomato production.

Crop Planning and Recordkeeping

Good record keeping skills can improve farm and business management and help you maintain recordkeeping requirements for organic certification. Records should be clear and easy to understand and should disclose all activities and transactions year after year. Organic certification also requires a specific set of recordkeeping documents called the Organic System Plan for crop production that verify that the producer is following the requirements for organic certification.

Crop Production Activity Record – use a crop production activity record to record all the activities you will conduct during the cropping season. Below is a sample Crop Production Activity Calendar.

Crop Production Activity Record														
Crop	Variety	Direct/ Transp	Days till harvest	No. rows	No. plants in row	Land prep. date	Irrig. date	Plant date	Germ date	Start harv date	End harv date	Total harvest	Total profit

Certification Recordkeeping: Organic System Plan – The Recordkeeping and Budget Workbook for Organic Crop Production is a document published by ATTRA—The National Agriculture Information Service and contains a set of forms for farmers to use to keep records required for organic certification. It includes basic templates for records that are ready for the barn, packing shed, pickup truck, or kitchen table—wherever is the focus of your daily farming activities. They may be used as is or readily adapted for different operations. Farmers are encouraged to modify these forms and tailor them to their production activities and farming business management (Born & Baier2005).

You can order these forms by calling ATTRA toll-free at: 1-800-346-9140 (English) 7am to 7pm Central Time and 1-800-411-3222 (Español) 8 am to 5 pm Pacific Time.

Or find them online at: http://attra.ncat.org/downloads/organic_cert/recordkeeping_budgeting.pdf

Crop Calendars are a great way to organize your crop plan for seasonal production. This method is used by farmers who like a more visual record of the month or days they will plant their crops; the growth period of each crop; and when the crops will be harvested.

Exercise: Crop Calendars

Color the boxes in yellow during the specific month each vegetable will be planted. Color the boxes in green during the growth period for each vegetable. Color in the boxes in red during the month each vegetable will be harvested.

VARIETY	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Artichokes												
Beans												
Broccoli												
Beets												
Corn												
Squash												
Tomato												

Harvest and Post Harvest Management

Harvest Maturity

There are many methods to determine produce maturity. The most common is the size of the individual item. Industry has set standards to which individual crops must conform (this usually does not apply to farmers who direct market). Size may be diameter and/or length. Another physical characteristic is firmness as determined with a brix pressure tester. Firmness is often correlated with chemical changes that occur during ripening. Chemical characteristics include soluble solids, iodine-starch test, and acidity. Soluble solids determine the sweetness of a crop, and the soluble solids to acidity ratio determine the overall flavor of the crop. The iodine starch test determines the amount of starch converted to sugar in a crop.

Days until maturity posted on seed packets will give an average maturity date based on previous records for the crop. The appropriate maturity stage will depend on the chosen market. Baby vegetables will have much different and earlier harvest dates than “mature” full size vegetables. If the produce is going into long-term storage, the maturity stage can be different, too. Different cultivars have different harvest maturities, too. If the produce is to be shipped, harvest in a less ripe stage so it will be firmer and travel better (2000 Gast).

When to Harvest

Harvest should be done during the coolest part of the day, which is usually the early morning. The shelf life of produce is closely tied to its respiration rate. The higher the respiration rate the shorter the shelf life. The respiration rate is directly related to the air and produce temperature. At high temperatures, the respiration rate is higher, so the shelf life of produce is reduced. Keeping the produce’s temperature low increases shelf life. Optimum storage temperature and harvest temperature differences should be kept to a minimum. By harvesting during the cool part of the day the differences will be minimized, the shelf life will be prolonged, and pre-cooling energy costs will be reduced. Besides waiting for the coolest part of the day, waiting for any surface moisture from dew or rain to dry will prevent post harvest disease problems (Wilson 1995).

How To Harvest

Specific harvest procedures for each crop will be covered in the **Families of the Day** section in this manual, but there are some general handling and harvest practices common to all produce. Produce should be handled with care to minimize mechanical damage. Mechanical damage renders the produce unmarketable and allows for disease organisms to enter. Some fruits and vegetables are more durable than others, but all should be treated with the same gentle handling. Handling and harvest containers and utensils should be cleaned and disinfected daily. This will reduce post harvest losses due to disease. Cutting utensils should be sharp to prevent damage to the plant. Workers should be trained on how to use sharp knives and shears safely to prevent needless injuries. Transport vehicles and field handling areas should be cleaned after harvest daily, too.

Besides harvesting during the cool part of the day, harvested produce should be kept as cool as possible. Field collection and handling areas should be shaded and produce should be moved to the packing, handling, and cold storage area as soon as possible.

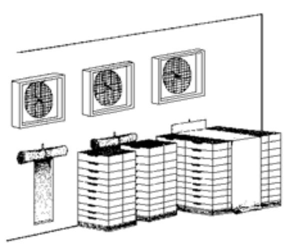
Post Harvest Management

Field Packing

Most people only think about grading and culling in the packing shed. The first steps in grading and culling should be done when you select what and what not to harvest. Most culling of diseased and inferior produce should be done in the field. They should be left in the field (or removed if diseased items are found). It is a waste of time and labor to handle unmarketable produce. It costs money, in time and labor, each time a fruit or vegetable is handled. It pays to only harvest and handle marketable produce and to minimize the number of times it is done. Some produce can be graded, cleaned, processed and packed into shipping containers in the field. The only handling steps left to do are pre-cooling and storage until it is sold and shipped (Gast 2000).

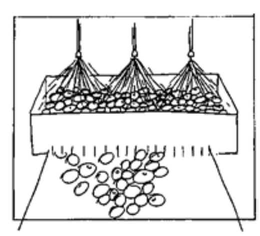
Storing and Refrigeration

One of the most important functions of refrigeration is to control the crop's respiration rate. Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavor, loss of salable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and post harvest life *(Bachmann & Earles 2001).* The higher the storage temperature, the higher the respiration rate will be. Some common refrigeration pre-cooling systems include:



Forced-air cooling

1) **Room cooling:** Produce is placed in an insulated room equipped with refrigeration units.
2) **Forced-air cooling:** Fans are used in conjunction with a cooling room to pull cool air through packages of produce.
3) **Hydro-cooling:** Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time.



Hydro cooling

4) **Top or liquid icing:** Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine.
5) **Vacuum cooling:** Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues.

Relative Humidity

Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95 percent), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used. Even buckets of water will increase humidity as the fans blow air across the water's surface and increase evaporation. Keeping the floor wet is helpful, though messy and potentially hazardous to two-legged creatures; frequent cleansing with a weak chlorine solution will be needed to prevent harboring of disease organisms in water and produce scraps on the floor. Crops that can tolerate direct contact with water may be sprinkled to promote high relative humidity *(Bachmann & Earles 2001).*

Ethylene

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to diseases. Ethylene "producers" should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury.

Commodities that are affected by ethylene include cabbage, carrots, lettuce, various greens, watermelons, kiwifruit, nursery stocks, and some kinds of flowers and florist greens.

Commodities that are known to produce considerable ethylene are apples, avocados, bananas, pears, peaches, plums, cantaloupes, honey dew melons, and tomatoes. *Penicillium digitatum* (green mold of citrus) and probably other decay organisms also produce ethylene, so decayed produce should be removed promptly from storage rooms (Wilson 1995).

Food Safety

Food safety, with emphasis on sanitation, is of great concern to produce handlers, not only to protect produce against post harvest diseases, but also to protect consumers from food borne illnesses. *E. coli* 0157:H7, *Salmonella, Chryptosporidium, Hepatitis,* and *Cyclospera* are among the disease-causing organisms that have been transferred to humans via fresh fruits and vegetables. (Suslow 2007) Use of a disinfectant in wash water can help to prevent both post harvest diseases and food borne illnesses.

Chlorine in the form of a sodium hypochlorite solution (for example, Clorox™) or as a dry, powdered calcium hypochlorite can be used in hydro-cooling or wash water as a disinfectant. Some pathogens such as *Chryptosporidium*, however, are very resistant to chlorine, and even sensitive ones such as *Salmonella* and *E. coli* may be located in inaccessible sites on the plant surface. For the majority of vegetables, chlorine in wash water should be maintained in the range of 75–150 ppm (parts per million.) The antimicrobial form, hypochlorous acid, is most available in water with a neutral pH (6.5 to 7.5) (Bachmann & Earles 2001).

Organic growers must use chlorine with caution, as it is classified as a restricted material. The California Certified Organic Farmers regulations permit a maximum of 4 ppm residual chlorine, measured down-stream of the product wash. Chlorine is widely used to sanitize fresh-cut fruits and vegetables. However, its effectiveness is limited with some products, e.g., suppressing growth of *Listeria monocytogenes* in shredded lettuce or completely eliminating *Salmonella montevideo* from inoculated tomatoes. Furthermore, some food constituents may react with chlorine to form potentially toxic reaction products. Therefore, there are some alternatives to use of chlorine such as hydrogen peroxide, ozone, trisodiumphosphate.

Hydrogen peroxide, for example, can be used in concentrations of 0.5 percent or less and has a low toxicity rating and is generally recognized as having little potential for environmental damage. The ATTRA resource list Sources for Organic Fertilizers and Amendments http://attra.ncat.org/attra-pub/orgfert.php has several sources of food-grade hydrogen peroxide.

At a cost of $2–8 each, woven polyester or nylon bags to place crops in for sanitation are durable, lightweight, water-permeable, and fast-drying. Suitable mesh laundry bags may be found at hardware or discount stores. Spin-drying can be done with a washing machine, honey extractor, or commercial salad spinner. A restaurant or industrial-scale salad spinner is an efficient machine for both washing and drying greens (available from restaurant supply stores; prices range from $650 to $1500) (Suslow 2007).

Cost of Production

Cost of crop production practices are all the resources that go into producing agricultural crops. In general, costs are based on land, common production and management practices. All costs are individualized to meet the specific needs of each grower.

Land – Land costs (buying, renting) based on the total number of acres used for production, location, quality of soil, proximity of water and other factors.

Production Practices – Input costs (land preparation, fertilization, transplanting, harvesting, post-harvest costs) usually in the order operations are performed. Labor, materials, fuel and repairs are also included in these costs. Production costs are also known as Operational or Cultural Costs in Cash Flow projections. These costs can be further broken down as shown below.

1. Irrigation costs – include buying and installing the irrigation system (drip tape or sprinklers etc.), maintenance, repairs and water costs.
2. Direct seeding and transplanting costs – include buying seeds and transplants (including cover crops), preparing land and the labor in cultivating each crop. Timing of these operations are dependent on planting schedules for each crop.
3. Pest, disease and weed management costs – include costs of various pest, disease and weed management controls such as pesticides, herbicides, mulch, biofertilizers, cover crops, mulches, biofumigants, biological controls, etc.
4. Harvest costs – include labor or contracted labor costs, field or shed packing, sorting, grading, custom and commission costs during harvest.
5. Labor costs – Calculate hourly wages for workers, machine operators and field workers. Farm worker SDI, FICA insurance and other benefits. Labor cost for equipment set-up, transport, etc.
6. Investment costs – depreciation and opportunity costs on an annual price per acre basis.

7. Equipment costs – Costs on a per acre basis and include: original cost of equipment plus sales tax, depreciation using straight line method, interest on investments.
8. Fuel and repair costs – fuel and repair costs per acre for each operation. Prices of on-farm delivery of gasoline and diesel per gallon respectively.
9. Administrative costs – recordkeeping costs during the production season including record books, computer software, office supplies etc.

Exercise: Cost of Production

You are assigned to research the cost of production mentioned above.

Assignment: Crop Plan – Please answer the questions below in detail.

1. Which crops did you select?
2. What is the basic botany of your crops?
3. What is the life cycle of your crops: Annuals, Biennials, and Perennials?
4. How will you prepare you beds?
5. What types of cropping systems will you use?
6. When will you plant your crops?
7. What is the optimal temperature for plant growth for your crops?
8. Will you use a successive planting scheme? How?
9. What is the planting depth of your crops?
10. What is the planting distance of your crops?
11. What are the seeding rates for direct seeding and transplants for your crops?
12. Will you use a type of season extension for your crops? What?
13. When will you harvest your crops? How will you harvest your crops?
14. What post harvest management practices will you use for your crops?
15. How will you keep records during crop planning and production?
16. List the cost of production

Resources

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Crop Plan: Glossary of Terms

Acre – An acre is a measure of land calculated at 43,560 square feet or 4,840 square yards or 1/640 square mile or about 0.404 687 3 hectare.

Annual – A plant that usually germinates, flowers and dies in one year.

Annual frost free days – The number of days from the last spring frost to the first fall frost.

Area of production – The length and width of your production area.

Bed Preparation – the process of building bed rows mechanically or manually for crop production.

Beneficial Habitats – Intercropped/companion plants that providing a desirable environment for beneficial insects and other arthropods — especially those predatory and parasitic species which help to keep pest populations in check.

Biochemical Pest Suppression – some plants exude chemicals from roots or aerial parts that suppress or repel pests and protect neighboring plants.

Biodegradable mulches – A protective covering, usually of organic matter such as leaves, straw, or peat, placed around plants to prevent the evaporation of moisture, the freezing of roots, and the growth of weeds.

Biodiversity – the abundance of different plant and animal species found in an environment.

Biofertilizer – a large population of a specific or a group of beneficial microorganisms for enhancing the productivity of soil.

Biofumigants – A sustainable methods of pest control involving the incorporation of crop residues that break down to release anti-pathogenic or anti-nematode compounds in the soil.

Biological control agent – organisms that control pests. They include predators, pathogens, parasitoids and weed feeders.

Botany – The scientific study of plants, including their physiology, structure, genetics, ecology, distribution, classification, and economic importance.

Cold Frame – a construction of four walls to trap heat and shelter plants, and a transparent lid that admits light. These are often used in winter months

Companion planting – the establishment of two or more plant species in close proximity so that some cultural benefit (pest control, higher yield, etc.) is derived.

Cost of Production – Cost of crop production practices are all the resources that go into producing agricultural crops.

Cover cropping system – Planting a non-crop species in order to cover the fields in between cropping cycles and to provide soil cover.

Crop Calendars – show what months you can expect to see specific crops become available throughout the growing season.

Crop Planning – The process of recording all the activities involved in growing your crops. Using the comprehensive list of vegetable, each with detailed cultivation instructions you can keep track of each seasons plantings and record the following: Type and variety of crop, Where planted/transplanted, Germination dates, Harvesting, Irrigation dates, planting distance, etc.

Crop Production – Crop production is a complex business, requiring many skills (such as biology, agronomy, mechanics, and marketing) and covering a variety of operations throughout the year using best management practices recommended to minimize environmental problems.

Crop Production Activity Record – use a crop production activity record to record all the activities you will conduct during the cropping season.

Crop Production Recordkeeping – The process of keeping financial and production information on your farm which can help monitor and evaluate the progress of your farm business.

Crop rotation – a cropping system method that is based on alternating crop families grown in a given field from one growing season to the next.

Crop selection – The main consideration in selecting the crops for production is market demand, what agronomic practices or soil and weather conditions are suitable, and funding needed to produce the crop.

Cropping systems

Days to maturity – The number of days from when a seed is planted till crop is mature and ready to harvest.

Direct seeding – planting seeds directly into the soil.

Diversification – the act of introducing variety into a cropping system.

Embryo – A plant embryo is part of a seed, consisting of precursor tissues for the leaves, stem (or hypocotyl), and root (or radicle), as well as one or more cotyledons.

Ethylene – a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it.

Fallow cropping system – Planting no crops in the ground with either weeds taking hold, or planting a grass cover crop to smother the weeds and keep the soil covered.

Field Packing – During the harvesting stage vegetables and fruits are packed manually or mechanically in the field. This process also includes cooling, cleaning, and sorting.

Food Safety – The concept that involves keeping food free from toxins, pesticides, and chemical, physical contaminants, and microbiological pathogens such as bacteria, parasites, and viruses that can cause illness.

Greenhouses – A construction with a transparent roof that lets in filtered light where plants are grown under controlled environmental conditions.

Hedgerows/ Buffer Vegetation system – Planting trees or shrubs around the perimeter of fields, along pathways of a farm, or to mark boundaries. They can provide protection from the wind, exclude animals, and produce an array of tree products.

Harvest Maturity – Period when fruits and vegetables are at the proper stage and size and at peak quality.

Herbicide – Used to kill unwanted plants. Selective herbicides kill specific targets while leaving the desired crop relatively unharmed.

High Organic Matter Input system – Introducing composts, incorporating crop residues into the soil, cover cropping, diversifying crops, biofertilizers, etc.

High Tunnels – greenhouse-like structures which modify the climate to create more favorable growing conditions for crops.

Integration of Livestock and pollinators systems – Integrating animals and bees into the production field.

Intercropping system – Planting two or more crops together in a single row.

Natural Pest Management – Pest management without the use of synthetic pesticides – instead the use of biological methods of pest control, including the breeding of pest-resistant crop varieties, the development of crop culture methods that inhibit pest proliferation, the release of predators or parasites of the pest species, and the placement of traps baited with the pest's own sex attractants is employed.

Nurse Cropping – A companion crop that fosters the development of another crop species, usually by protecting the second species, during its youth, from frost, insolation, or wind.

Organic System Plan – Also known as a Farm Plan, it is a tool that helps farmers assemble the necessary documentation to apply for organic certification through an accredited certifying agent. A complete Organic System Plan consists of one or more of the following elements, as appropriate to the individual operation: an Organic Farm Plan, an Organic Livestock Plan, and an Organic Handling Plan.

Percent germination – Germination percentage is an estimate of the number of viable seeds in a population.

Perennials – a plant that usually germinates, flowers and dies in one more than one year.

Pesticides – A pesticide may be a chemical substance, biological agent (such as a virus or bacteria), antimicrobial, disinfectant or device used to kill a pest.

Plant resistance to pest and disease – the ability of a plant variety to restrict the growth and development of a specified pest or pathogen and/or the damage they cause when compared to susceptible plant varieties under similar environmental conditions and pest or pathogen pressure.

Plant stages – The various phases of a plant's life cycle (egg, larva, adult).

Plant variety-A plant variety is a subdivision of a specific plant species.

Plant yield – harvesting crop material intended for consumption, use and/or market sale.

Planting Depth – Planting depth refers to how deep the plant has been sunk into the soil.

Planting Distance – The distance plants are planted between another plant and/or row.

Planting times – Time of the season, soil and weather conditions adequate for planting crops.

Post Harvest – In agriculture, post harvest is the stage of crop production immediately following harvest, including cooling, cleaning, sorting and packing.

Record keeping – Keeping written information that monitors the progress of your farm and business, prepare your financial statements, identify source of receipts, keep track of deductible expenses, and prepare your tax returns.

Reduced or Minimum tillage system – Reducing the intensity of soil cultivation and leaving residues on the surface with little disturbance to the soil.

Relative Humidity – The ratio of the amount of water vapor in the air at a specific temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage.

Rotation systems – Planting different crops one season after another or in "succession".

Row – is the length and width of a prepared crop bed.

Row covers – A row cover is simply a piece of cloth that growers use to cover plants for frost protection, inclement weather, chemicals lifted by wind, insect protection, conserving soil moisture, improved seed germination, and season extension.

Season extension – a range of cultural practices that simply "extend" how long you are able to grow a crop during the season.

Seeds – A small embryonic plant enclosed in a covering called the seed coat.

Seeding Rate – The amount of seed planted in a given area. Seeding rate often depends on (1) the desired number of plants per acre (plant population), which depends on the spatial arrangement (within-row and between-row spacing) of the plants, (2) the number of seed per pound, (3) the percent germination and (4) planting precision.

Selling period – Growers have to decide the best times to sell their crops.

Seedling – A **seedling** is a young plant developing out of a plant embryo from a seed. Seedling development starts with germination of the seed. A typical young seedling consists of three main parts: the radicle (embryonic root), the hypocotyl (embryonic shoot), and the cotyledons (seed leaves).

Site Selection – the process of choosing an area for crop production.

Sorting and Grading – Any process of arranging items in some sequence and/or in different orders, ratings, or categories (variety, size, weight, color etc.)

Storing and Refrigeration – A harvested crop is stored in a cool and contained placed such as a storage shed or refrigeration cooler to reduce excess water and weight loss, the respiration, ripening, maturation and aging processes. There are many types of refrigeration processes: (1) Room cooling, (2) Forced air-cooling, (3) Hydro-cooling, (4) top or liquid icing, (5) Vacuum cooling.

Strip cropping system – Planting a single crop in one row and then a different crop in the next row or strip.

Successive planting – the process of scheduling crops in order to produce a continuous harvest each week.

Sustainability – the concept of producing a crop under management practices that ensure replacement of the part harvested, by regrowth or reproduction, before another harvest occurs.

Symbiotic Nitrogen Fixation – Legumes—such as peas, beans, and clover—have the ability to fix atmospheric nitrogen for their own use and for the benefit of neighboring plants via symbiotic relationship with Rhizobium bacteria.

Transplants – Technique of moving a plant from one location to another. Most often this takes the form of starting a plant from seed in optimal conditions, such as in a greenhouse or protected nursery bed, then replanting it in another, usually outdoor, growing location.

Trap Cropping – *Trap cropping* is the planting of a *trap crop* to protect the main cash *crop* from a certain pest or several pests.